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Economic effects by merger and acquisition types in the renewable energy sector: An event study approach

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ABSTRACT

This study classifies the types of mergers and acquisitions (M&A) carried out in the renewable energy industry and explores their effects on enterprise value. Both the generalized autoregressive conditional heteroskedasticity and the ordinary least squares methodologies are used in an event study in order to improve the reliability of the presented analysis. In order to understand how M&A type affects enterprise value depending on the inter-relationship between the acquirer and target business, M&A cases are divided into four groups: homogeneous, heterogeneous-renewable, heterogeneous-energy, and heterogeneous-other. From this analysis, four implications can be drawn. First, homogeneous M&A shows the biggest effect on enterprise value, indicating that operating synergy and increasing market power are important factors when renewable energy firms undertake M&A. Second, M&A with other industries of which financing companies take part in most show the second largest effect on enterprise value, meaning that renewable energy is considered to have potential as an investment product. Further, in the analysis of the wind power industry, the result that heterogeneous-other M&A shows an even greater effect suggests that wind power is deemed to have a high potential for growth as an industry for investment. Lastly, renewable energy M&A in existing energy industries have negative effects on enterprise value, indicating that strict regulations on the use of clean energy such as renewable energy result in energy companies incurring considerable costs.

Contents

1. Introduction

Mergers and acquisitions (M&A) occur when a new technology appears in the relevant industry. They take place for a number of reasons, including a supply shock to secure productivity, policy changes, or the activation of the external capital market [1,2]. Because there is huge demand for alternative energy sources to reduce carbon emissions, the renewable energy industry has

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rapidly become a suitable environment for M&A. Indeed, the M&A of renewable energy companies (renewable energy M&A hereafter) increased by 70% in 2010 alone and this trend is continuing to grow [3,4]. There has been substantial research on how M&A affect enterprise value and industrial competence in the energy sector. For example, Kwoka and Pollitt [5] and Verde [6] are among those scholars that argue that mergers can be positive. Kwoka and Pollitt [5] showed that M&A positively affect the US electricity industry, while Verde [6] reported that M&A have positive effects on the gas and electricity industry in the EU. By contrast, Choi and Song [7] and Wårell [8] analyzed how M&A influence the oil and steel industries and both studies concluded that they bring about negative effects.

However, little academic research has been carried out on renewable energy M&A. The only study was Eisenbach et al. [9], which showed the positive effect of M&A on the profits of solar energy with other renewable energy firms. However, it only focused on the significance of mergers on each source of renewable energy, without considering various types of M&A. Hence, there remains a need for a systematic approach to analyze renewable energy M&A.

This study thus classifies the types of renewable energy M&A and explores the effect on enterprise value. The types of renewable energy M&A were divided into related diversification and unrelated diversification depending on their motivation. Related diversification refers to M&A between businesses that produce the same product, while unrelated diversification means M&A between businesses that do not produce the same product [10]. According to diversification theory, we further divided renewable energy M&A into four types: homogeneous, heterogeneous-renewable, heterogeneous-energy, and heterogeneous-other M&A.

This paper focuses on determining whether these four types of renewable energy M&A have different effects on enterprise value. In addition, it examines how these types of M&A influence a subdivision of the renewable energy sector (i.e., the wind energy industry). The generalized autoregressive conditional heteroskedasticity (GARCH) and ordinary least squares (OLS) models were used in the event study methodologies in order to improve the reliability of the presented analysis.

The remainder of this paper is organized as follows. Section 2 investigates the latest trend and significance for all types of renewable energy M&A and explains the event study method, a methodology for empirical analysis. Section 3 analyzes the data. Section 4 describes and explains the result of this analysis. Section 5 concludes and suggests policy implications.

2. Theoretical background of renewable energy M&A

2.1. Literature review on M&A effect analysis

Businesses adjust their strategies in order to survive and grow in rapidly changing environments. Firm growth can be divided into internal growth and external growth. Internal growth is a strategy to grow through accumulating profits by management rationalization such as expanding investment, increasing production, and improving sales. External growth is a strategy to grow by acquiring some or all of the assets of another company. M&A are a major approach to external growth.

Choi and Kim [4] defined M&A as a change in the control of a company in terms of human and physical resources. A merger combines two enterprises into one integrated company. This can be achieved in two main ways: (i) a company that continues to legally exist takes over another company's assets and liabilities or (ii) all companies subject to the merger are dissolved and a new company is established to which all asset and liabilities are transferred. By contrast, acquisition is a method of obtaining the management right by purchasing the target company's shares and/or assets and aims to acquire control of the company rather than making a simple investment into it.

According to Rumelt's study [10], M&A can be divided into related and unrelated diversification depending on the interrelationship between existing and new business. It is an important management decision for a company to decide whether to follow related diversification, whereby a firm can secure expertise and improve competitiveness by focusing on one business, or choose unrelated diversification, whereby it can increase profitability and spread risk by diversifying into different businesses.

Although there have been no previous studies of how these types of renewable energy M&A influence business performance, there has been active research on how diversification affects business performance. Earlier studies of diversification focused on investigating a firm's performance after diversification. Most of the results suggested that related diversification positively affects business profitability and contributes to reducing risks. In Rumelt's study [10], four major and nine minor diversification categories were defined by specialization ratio and related ratio. By analyzing the financial performances of 246 diversified firms, he showed that constrained diversification by a firm that shares common core skills, strengths, or resources outperforms other diversification strategies. This result was reaffirmed by the findings of Christensen and Montgomery [11] and Palepu [12]. Christensen and Montgomery [11] attempted to explain firm performance in terms of market structure and ascertained that because constrained firms tend to operate in highly profitable markets they perform better. Palepu [12] also found that related diversifiers' profit growth is significantly higher than that of unrelated diversifiers. Moreover, Montgomery and Singh [13] incorporated the concept of systematic risk and demonstrated that systematic risks for unrelated diversifiers are higher than other diversified firms' risks.

However, substantial research also shows the opposite result [14–16]. In particular, Gottschalg and Degenhard [16] found that the availability of headquarter resources, which are at the basis of the headquarter services provided to business units, is the driving force behind unrelated diversification. Christensen and Montgomery [17] alternatively suggested that industrial structure has an immense influence on diversification. According to them, the industrial structures of highly profitable industries positively affect firm performance within the industry and simultaneously encourage companies to promote related diversification. By contrast, the industrial structures of low-profitability industries not only negatively affect firm performance within the industry but also lead companies to prefer unrelated diversification.

Within the general theory of diversification and M&A, there has been ample discussion about which form of measurement can best quantify its effects. Event study methodology is a representative econometric method that can analyze the effects of M&A. This methodology assesses changes in the expected profit of a company to which an unexpected event has taken place. According to the efficient market hypothesis, a firm's stock price is the current cash value that reflects the future cash flow expected from a company's current assets. Therefore, unexpected events are reflected in stock price. In other words, by measuring the change in stock price before and after the unexpected event, the effect of this event on the enterprise can be measured [19].

Previous studies have shown that this method has broad applications for evaluating how an event affects the financial market in the fields of accounting and finance [8,20], law, energy [8,21,22], and economic shocks. M&A events have also been significantly studied [23]. Since Fama [24] used this methodology to analyze the information content of stock split announcements on the New York Stock Exchange, it has become the most

frequently used research method for empirical study in the finance and accounting fields, including M&A (see [7–9,21,22,25,26]).

Most researchers have thus far used the OLS estimation method in event studies despite its limitations [27–30], namely that it assumes a constant variance in both the pre- and the post-event windows. However, the autoregressive conditional heteroskedasticity (ARCH) effect has been shown to be significant in many financial series [31–33]. If we use OLS estimation methods and the variance is underestimated, the test statistic will lead to the rejection of the null hypothesis more frequently than should occur (for more details, see, [31,34–36]). This study thus applies the GARCH method (see below) to explain the conditional heteroskedastic effect in event studies and compare the results with the OLS method.

In order to generalize the assumption of constant variance required in traditional econometric models, Engle [37] developed a model that described a new class of stochastic processes called ARCH. The ARCH model specification was subsequently generalized to the GARCH model by Bollerslev [38] and Baillie and Bollerslev [39] in order to allow for past conditional variances in the current conditional variance equation [40]. The GARCH model consists of a mean equation and a conditional variance equation. The advantage of this approach is that it models the level of returns, as does the basic market model, and allows for time-varying volatility.

2.2. Motivation behind renewable energy M&A

Renewable energy M&A can be divided into related and unrelated diversification depending on the inter-relationship between the existing and new business. Related diversification is termed “homogeneous M&A” in this study. Unrelated diversification, which is termed “heterogeneous M&A” herein, can be further subdivided into “heterogeneous-renewable,” “heterogeneous-energy,” and “heterogeneous-other” depending on the acquirer's industry (Table 1).

Examples of related diversification in the renewable energy industry include M&A between solar energy companies, wind power companies, and biofirms. Each company may be at the same level or at different levels in the value chain of the same industry. By contrast, unrelated diversification means M&A between an acquirer and target companies that are in different industries. Heterogeneous-renewable represents M&A between companies that produce different renewable energy sources, heterogeneous-energy represents M&A between oil, gas, or electric power companies and a renewable energy company, and heterogeneous-other represents M&A by an investor or company from a different industry with a renewable energy company.

In order to understand how the discussed types of renewable energy M&A influence a firm's value, it is first necessary to understand the motivation behind M&A in each type (see Table 2). The motivations behind renewable energy M&A include financial synergy, operating synergy, increasing market power, risk diversification, green premium, and policy execution.

Synergy means the effect of creating value that is greater than the sum of the individual pre-M&A companies. Financial synergy means increasing firm efficiency through the combination of enterprises in order to reduce the cost of capital and expand the benefits of financing. Smaller renewable energy companies can mitigate their relatively high cash flow volatility by diversifying risk through M&A. In addition, the rapid growth of the renewable energy industry will facilitate firm financing, while the economies of scale in financing may create synergies that reduce the cost of capital transactions or issues per unit. Such financial synergy is expected in all types of renewable energy M&A.

Operating synergy leads to increased efficiency through economies of scale or scope in firm management. Homogeneous M&A are expected to generate operating synergy because M&A within the same industry can reduce cost per production unit by sharing production processes or knowledge throughout the expanded labor force and reducing overlapping expenditure on R&D, which is essential for technological development in the renewable energy industry.

Increasing market power aims to secure monopolistic profit by either raising market share or limiting competition through the expanded scale of the post-M&A company. This motivation appears most strongly in homogeneous M&A. Because the renewable energy industry is establishing separate value chains and

Table 1
Types of renewable energy M&A.

M&A type	Definition	Example
Homogeneous M&A	M&A within the same renewable energy industry	Solar–solar, wind–wind, bio–bio
Heterogeneous M&A		
Renewable	M&A within different renewable energy industries	Solar–wind, solar–bio wind–bio
Energy	M&A between a traditional energy company and a renewable energy company	Oil–solar, oil–wind, gas–bio, elect power–wind
Other	M&A between another industry's company and a renewable energy company	Investment–wind, conglomerate–solar

Table 2
Motives behind renewable energy M&A.

	Homogeneous M&A	Heterogeneous M&A		
		Renewable	Energy	Others
Synergy				
Financial synergy	O	O	O	O
Operating synergy	O			
Increasing market power	O			
Risk diversification		O	O	
Green premium			O	O
Policy execution			O	

markets for different energy sources, homogeneous M&A increases profits by expanding firm size, which reduces competition and increases prices. For instance, acquiring raw materials or shares in companies can damage competitors, while acquiring a distributor can influence the market by controlling the distribution channel.

Risk diversification through M&A is expected from heterogeneous M&A. Because risks vary depending on the types of acquirers, risk diversification in heterogeneous M&A is related to the technological aspects of renewable energy. Renewable energy creates electricity using natural resources such as wind and sunlight and thus it is subject to environmental change. To mitigate this problem establishing portfolios of renewable energy rather than one energy source can help diversify technological risks and prepare for the provision of future energy sources.

Given the growing interest in minimizing CO_2 emissions and environmental pollution, the green premium relates to how an environmentally friendly image can positively affect firm value. Chan [18] suggested that green companies are perceived to be less prone to corporate social crises and environmental disasters and thus command a premium compared with non-green firms. Renewable energy is representative of green energy. Therefore, the green premium effect could be particularly valuable to diversified acquirers not yet involved in renewable energy that could spill over the effect to non-green assets (e.g., the conventional energy industry).

Finally, the policy execution motivation is based on governmental measures to reduce CO_2 emissions, which is an incentive for existing energy companies to participate in M&A. As more and more policies to reduce CO_2 such as the Renewable Portfolio Standard (RPS) are prepared, energy companies must produce a certain proportion of electricity using low-carbon energy. They thus enter the renewable energy sector in one of the three ways: purchase clean energy produced by another company, engage in M&A with an existing renewable energy company, or enter the renewable energy sector alone. Although the above-described motivations are considered to positively affect stock price, M&A based on the policy execution motivation can incur costs.

3. Data and analysis

3.1. Event study analysis

In this paper, the event study methodology is carried out in the following six steps.

(1) Event definition:
First, the event is defined and the period of interest or “event window” identified. In general, the event window is extended to include multiple days before and after the event. In this paper, the event is renewable energy M&A, while three event windows and one normal returns estimation period are defined.

(2) Sample selection criteria:
Second, the target firms and their stock returns during the event window are determined. Stock returns are the daily returns and firm i's rate of return at t days, where P_t is the closing price at day t and P_{t-1} is the closing price at day $t-1$

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}} \tag{1}$$

(3) Measurement of normal returns:
Normal returns are expected stock returns under normal circumstances, namely when no unexpected events occur. Abnormal returns are the difference between true stock returns and normal returns. Since the value of abnormal returns depends on a model for forecasting normal returns, we compare two models, namely OLS (using the market model) and GARCH, in order to obtain a more accurate and impartial interpretation.

A. Normal returns of the OLS model
The normal returns of the OLS model are defined as

$$R_t = \alpha + \beta R_{mt} + \varepsilon_t \tag{2}$$

where R_t is the stock returns of firm i at day t and R_{mt} is the stock returns of the market at day t.
The stock returns of a market are an appropriate market index, and we use the representative of each market index to which the firm belongs. ε_t is an error term for the changes that cannot be explained by overall changes and whose distribution is *iid* $N(0, \sigma_i^2)$. Based on these estimated parameters, we calculate normal returns.

B. Normal returns of the GARCH model
The normal returns of the GARCH model are presented below using additional parameters in the mean equation and the addition of a variance equation. The mean equation in the GARCH (p, q) model is defined as

$$R_t = \alpha + \beta R_{mt} + \sum_{h=0}^{H} \lambda_h r_t + \varepsilon_t \tag{3}$$

The conditional variance equation in the subdued GARCH (p, q) model is defined as

$$\varepsilon_t | \Omega_t \sim N(0,\ h_t) = \varphi_0 + \sum_{k=0}^{q} \varphi_k \varepsilon_{t-k}^2 + \sum_{j=1}^{p} h_{t-j} \tag{4}$$

To estimate the GARCH model, the ARCH term p and GARCH term q must be established in the appropriate order. Many previous studies have shown that the volatility of financial variables lasts for a long time and that a simple GARCH (1, 1) model thus holds well (see [41]). In addition, McKenzie et al. [20], Wang et al. [40], and Batchelor and Orakcioglu [42] also chose GARCH (1, 1) models in their event studies. We consider these findings in our model by applying GARCH (1, 1) to the error term. For data with iteration concerns, we also applied ARCH (1). In the estimation stage, we use the maximum likelihood estimation method.

(4) Abnormal returns:
Abnormal returns (AR) are defined as follows:

$$AR_t = R_t - (\alpha + \beta R_{mt} + \varepsilon_t) \tag{5}$$

Based on this equation, abnormal returns are the difference between true stock returns (R_t) and normal returns ($\alpha + \beta R_{mt} + \varepsilon_t$).

(5) Aggregation of abnormal returns:
The estimated effect of the event throughout the entire event window is determined by adding each t day's abnormal returns separated over time. This added value is called the cumulative abnormal return (CAR). Prior to this process, the representative value of each group must take account of the average abnormal returns of the firms in each group

$$AAR_t = \frac{1}{N} \sum_{i=1}^{N} AR_{it} \tag{6}$$

$$CAR_t(t_1,\ t_2) = \sum_{t_1 - t_2} AAR_{it} \tag{7}$$

where t_1 is the starting date, t_2 is the ending date, and N is the number of firms.

(6) Null hypothesis test:
The hypotheses are defined and the t statistics for testing

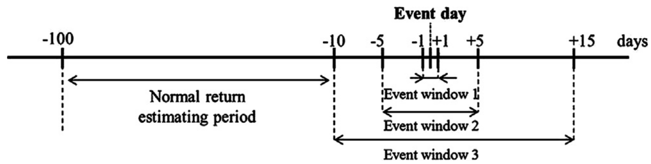

Fig. 1. Normal return estimating period and event windows.

statistical significance calculated. The null hypothesis is H_0: $CAR=0$ and this is tested for each M&A type. The statistics used in this paper are defined as

$$t=\frac{CAR(t_1,\ t_2)}{[\mathrm{var}(CAR(t_1,\ t_2))]^{1/2}} \tag{8}$$

3.2. Data

The sample comprises firms that announced renewable energy M&A during the study period of 2008–2010. M&A data were collected mainly from MarketLine,[3] although we also used reports from accounting firms and Bloomberg articles. MarketLine offers a comprehensive collection of company, industry, financial, product and country information, research and data extending across every major marketplace and industry. Based on the collected M&A data, the DataStream data service[4] was mined for individual stock data and stock market data on the sample companies. DataStream is a large-scale financial and macroeconomic database that provides statistics on equities, company fundamentals, fixed income securities, and economic indicators for 180 countries and 60 markets.

To filter out unhelpful information on individual firms, the following three inclusion criteria were applied:

(1) The companies were represented in MarketLine's renewable energy category.
(2) The firm's stock data between 100 days before and 15 days after the event were available from DataStream.
(3) The normal rate of return model was statistically significant.

As indicated from criterion (2) above, the data used for the presented analysis were firm stock data from 100 days before (signified as −100 hereafter) to 15 days after (i.e., +15) the investigated event. By using returns data from −100 to −10 and employing the OLS and GARCH methods, a normal returns model was presumed. The AR was calculated regarding the subsequent event day and three event windows studied in this paper. Window 1 represents one day before and after the event [−1; +1]; window 2, 5 days before and after [−5; +5]; and window 3, 10 days before and 15 days after [−10; +15]. Fig. 1 clarifies these periods.

Sample data were based on the acquirer in the M&A process. In most M&A, acquiring leads to the absorption of the target firm and, therefore, the stock data on the company is no longer publicly available. Because the effect of M&A on enterprise value can depend on the relative positions of the acquirer or target firm, it is appropriate to look at the acquirer's data in order to consider its significance. Further, most studies that have investigated how M&A affect enterprise value have used acquirers' data for analysis [7–9,21,22,25]. Thus, this study restricted company data to those of acquirers, which limited the presented findings to the effect of renewable energy M&A on the acquirer's stock price.

[3] http://www.marketline.com/.
[4] https://forms.thomsonreuters.com/datastream/.

Table 3
The distribution of sample cases by M&A type.

M&A type	Acquirer	Target	Number
Homogeneous M&A	Solar	Solar	5
	Wind	Wind	5
	Bio	Bio	3
	Total		13
Heterogeneous M&A	Renewable	Solar	1
		Wind	4
		Others	4
		Total	9
	Energy	Wind	8
		Bio	2
		Others	5
		Total	15
	Other	Wind	3
		Bio	4
		Others	3
		Total	10
	Total		34
	Total		47

After filtering the data using these criteria, 47 M&A cases were used in the analysis. Acquirers are from 18 countries including the United States, Canada, China, and Germany. There were 13 homogeneous M&A cases consisting of solar (five cases), wind (five cases), and bioenergy (three cases) companies, and 34 heterogeneous cases with nine M&A cases from the renewable energy industry, 15 with traditional energy companies, and 10 with companies from a different industry. Thus, approximately 70% of M&A were undertaken by unrelated diversification.

Among these sample cases, M&A with traditional energy companies, such as oil and gas or electricity utility companies, were the most common (32%), while over half were in the wind energy industry. The number of M&A between companies of different renewable energy resources was the smallest (including many firms acquired by wind energy companies), while in the case of M&A with firms in other industries, 70% were investment companies (Table 3).

4. Results

Table 4 shows the results of the event study analysis after applying OLS and GARCH to all types of renewable energy M&A. After determining the AR of each point from the predicted OLS result, the CAR values shown in the table were calculated by adding the AR of the event window. A bigger CAR means a bigger shock to the accumulated stock price owing to the M&A. In order to assess whether the size of the shock was statistically significant and to test the null hypothesis that abnormal returns are zero, two-sided t-tests were conducted on the CARs. Statistically significant (+) CARs increased stock prices, whereas statistically significant (−) CARs reduced them.

The four types of renewable energy M&A considered in this study all significantly affected enterprise value. Among them, homogeneous M&A turned out to have the most positive effect. The GARCH CAR of homogeneous M&A during the [−10; +15] period was 10.593, which is 3.02 times bigger than that of heterogeneous-other, the second highest CAR value during the same period. In the homogeneous M&A analysis, all CARs during the other event windows, except the [0] period, were significant, and the longer the window, the bigger the CAR tended to become. The CAR of [−10; +15] was 3.57 times bigger than that of the [−1; +1] period. This result implies that the effect of homogeneous

Table 4
CARs of the four event windows by M&A type.

	Homogeneous M&A		Heterogeneous M&A					
			Renewable		Energy		Others	
	OLS	GARCH	OLS	GARCH	OLS	GARCH	OLS	GARCH
[−10;+15]	8.805*** (17.072)	10.593*** (17.265)	0.990 (−0.594)	2.486*** (3.774)	−3.384*** (−10.191)	−1.675*** (−8.434)	3.391*** (6.746)	3.500*** (6.550)
[−5;+5]	3.493*** (12.226)	4.424*** (12.140)	0.572 (−0.985)	1.247 (0.846)	−3.629*** (−10.286)	−2.716*** (−10.737)	2.311*** (3.876)	2.430*** (3.875)
[−1;+1]	2.597** (4.770)	2.967** (5.073)	−0.373* (−3.187)	−0.166 (−1.964)	−1.631 (−2.466)	−1.409 (−2.217)	−2.486* (−3.053)	−2.598* (−3.024)
[0]	26.944 (2.2174)	28.3614 (2.3657)	−2.233* (−3.004)	−1.970 (−2.4679)	−8.343** (−4.104)	−7.422** (−3.8327)	−14.339** (−4.3394)	−14.176** (−4.420)
Obs	13		9		15		10	

(1) *, **, *** significant at 10%, 5% and 1%, respectively (2) standard errors in parentheses.

M&A is accumulative rather than disappearing after a short period. Homogeneous M&A were the only type that had positive values in all four event windows, which can be interpreted as a sign of the positive effect of M&A.

In the heterogeneous M&A analysis, the same tendency appeared regardless of the type during the initial period of M&A. During the [0] and [−1; 1] event periods, all three groups had negative CARs. However, the significance of CARs varied by group. In heterogeneous-renewable M&A, only the OLS prediction was significant, in heterogeneous-energy M&A, only [0] periods were significant, and in heterogeneous-other M&A, both the [0] and [−1; 1] periods were significant. These differences in statistical significance, given that the same period in the homogeneous M&A analysis showed positive CARs, imply a negative effect on enterprise value during the initial period.

In the heterogeneous M&A analysis, when an event window was long, different effects appeared. While heterogeneous-renewable M&A positively affected the stock price of a company, this seemed to fall for general energy firms. Further, as the event window extended for heterogeneous-renewable M&A, CARs became positive (with a 2.486 value during the [−10; +15] period) and significant. This indicates that M&A with other renewable industries do not influence enterprise value in the short-term, but do so in the long-term.

As for heterogeneous-energy, even a prolonged event window led to negative CARs. This shows the clear reduction in stock prices following M&A. The CAR values of the [0], [−1; 1], [−5; +5], and [−10; +15] periods were −7.422, −1.409, −2.716, and −1.675, respectively. Except the CAR of [−1; 1], they were all statistically significant. In particular, the [0] period showed the biggest shock, while longer event windows showed less shock. Although heterogeneous-energy M&A are thought to incur huge costs, this negative effect decreases over time.

For heterogeneous-other M&A, as the event window extended, CARs became statistically significant and positive. The CAR of the [−5: +5] period was 2.430, while that of the [−10:+10] period was 3.500. Here, companies that belong to other industries included an investment firm or conglomerate. In other words, when companies in these fields enter the renewable energy industry, they incur short-term costs but generate positive effects on enterprise value, in the long run.

To summarize, the related diversification types of M&A (homogeneous M&A) can be expected to show clear positive effects, whereas the unrelated diversification types of M&A (heterogeneous M&A), despite initially showing negative effects, led to a positive effect on the heterogeneous-renewable and heterogeneous-other M&A and to a negative effect on heterogeneous-energy M&A in the long run.

In this next stage of the analysis, this research assessed the wind power industry in order to investigate whether the differences among different types of renewable energy M&A can be generalized to individual renewable energy sources. We chose wind power as the subject of this further analysis because it had the largest amount of data and included all types of M&A.

Table 5 showed similar results to the analysis of the renewable energy sector as a whole. Barring differences in statistical significance, all CARs showed the same signs (except the [0] period). For homogeneous M&A, all event windows showed positive signs. Moreover, for heterogeneous M&A, shorter event windows showed negative effects, while over longer periods, other renewable energy and other industry M&A had positive effects and other energy industry M&A negative effects. This robust result is based on an increase in enterprise value following homogeneous M&A, which was analyzed in the entire renewable energy sector previously, and a decrease in stock price following M&A compared with other energy sources.

However, the results of the entire renewable energy industry analysis and those of the wind power sector did not match perfectly. Oftentimes, a case that was significant in the former was not significant in the latter and vice versa. In particular, in homogeneous M&A only the [−10; 15] period was significant. Further, although the [−5:+5] and [−1; 1] periods were significant in the entire renewable energy industry, they were not for wind power. Likewise, although the [0] and [−1; 1] periods in heterogeneous-renewable were not significant across the entire industry, they were significant in the wind power sector. The high significance of heterogeneous-renewable M&A seems to be based on the technological characteristics of wind power, which is hugely affected by irregularity in terms of environmental conditions and thus the expectation for technological risk diversification is higher compared with other renewable energies.

Further, in the analysis of the entire industry, the effect of homogeneous M&A was the largest, whereas in wind power, M&A with other industries showed the largest effect. Indeed, the CAR during the [−10, 15] period was 13.514, 3.8 times that of the entire industry, implying that other industries fully consider the long-term effect of investing in the wind power industry.

Finally, although the OLS and GARCH analysis showed similar overall significance levels, not all results matched. In the analysis of other renewable energy in the entire industry, OLS showed the effects of M&A during the [−1;1] and [0] periods, whereas GARCH did not. This result agrees with those of previous studies that demonstrated the significance of applying GARCH models to event study analyses [33,40,43]. Corhay and Rad [31] found that, in an OLS model assuming constant residuals, information leakage near an event window led OLS to be statistically more significant compared with GARCH. Further, because stock return series generally display time-varying volatility and because GARCH allows

Table 5
CARs of the four event windows by M&A type in the wind power sector.

	Homogeneous M&A		Heterogeneous M&A					
			Renewable		Energy		Others	
	OLS	GARCH	OLS	GARCH	OLS	GARCH	OLS	GARCH
[−10;+15]	14.935*** (5.383)	10.263*** (4.321)	0.610** (2.174)	1.425*** (4.367)	−1.613*** (−10.946)	−0.691*** (−11.218)	12.642*** (7.557)	13.514*** (7.292)
[−5;+5]	8.614 (1.425)	6.935 (0.834)	1.188 (−0.508)	1.460 (0.158)	−2.250*** (−8.507)	−1.411*** (−8.644)	8.638*** (7.121)	9.076*** (6.973)
[−1;+1]	4.902 (2.110)	4.498 (1.996)	−1.074** (−7.305)	−1.035** (−7.628)	−0.204 (1.203)	−0.076 (1.700)	−2.992* (−3.245)	−3.337* (−3.091)
[0]	36.521 (2.321)	36.043 (2.282)	−3.122** (−4.549)	−2.918** (−3.825)	0.352 (0.172)	0.126 (0.063)	4.346 (1.299)	4.305 (1.278)
Obs	5		6		8		3	

(1) *, **, *** significant at 10%, 5% and 1%, respectively (2) standard errors in parentheses.

for non-linear intertemporal dependence in the residual series, this model is more efficient than is the OLS model.

5. Conclusions

This study analyzed how renewable energy M&A affect enterprise value by dividing the types of M&A into four groups, namely homogeneous, heterogeneous-renewable, heterogeneous-energy, and heterogeneous-other, and examining the incentives for each type to engage in such business transactions. Based on 47 selected cases of renewable energy M&A between 2008 and 2010, the effect on enterprise value was then empirically analyzed. This study also improved the robustness of the analysis by separately assessing the wind power industry.

The results can be summarized into the following four points. First, among the four types of renewable energy M&A, homogeneous M&A showed the biggest effect on enterprise value. In the wind power analysis, homogeneous M&A also had a substantial effect, although heterogeneous-other M&A showed the biggest effect. This result indicates that operating synergy and increasing market power are efficiently generated when renewable energy firms undertake M&A. It is also in accordance with the results of previous studies that supported the advantages of related diversification [10–12]. In the renewable energy industry, the efficient management of the value chain of each energy source is an important factor for business growth, because the price increases of essential parts lead to overall price increases, which reduce firm profit. In addition, given the unstable market circumstances, producing supply-led products can also negatively affect profit. It seems as though enterprise value increases when flexibility in the face of industrial changes is reflected through M&A within the same industry.

Second, among heterogeneous-types, M&A with other industries showed a huge effect on enterprise value. Financing companies were shown to have taken up a large percentage among the firms from other industries included in the analysis. This suggests that renewable energy is considered to have potential as an investment product. Indeed, the renewable energy industry has large potential for growth based on internal and external factors. Internally, the unit cost of production is falling because of technological development, while, externally, the depletion of conventional energy sources such as oil and gas is increasing prices, resulting in greater price competitiveness for renewable energy. Further, the expansion of the renewable energy industry is essential for reducing CO_2 emissions [44,45]. Thus, it seems as though investors are aiming to obtain financial synergy by investing in renewable energy through M&A with these possibilities in mind.

Further, the even greater effect of heterogeneous-other M&A in the wind power analysis indicates that wind power has high growth potential as an industry. The technological development of such power has progressed to the point that by 2016 electricity produced by onshore wind farms will cost the same as that from fossil fuel-driven plants [46]. In addition to countries such as Spain, Germany, and Denmark that have continuously invested in wind power since the 1980s, the US and China are now preparing policies for wind power distribution. This rising usage of wind power has resulted in double-digit annual growth since 2006, while in 2011 an additional 20.2 GW, 19% more than in the previous year, was installed [47,48].

Lastly, renewable energy M&A of existing energy industries showed negative effects on enterprise value. The biggest difference between heterogeneous-energy M&A and the other types of M&A is in policy execution. In other words, the introduction of climate change measures to reduce CO_2 emissions such as RPS and “cap and trade” strongly requires the use of clean energy [49]. In particular, electricity firms are obliged to produce approximately 30% of electricity using low-carbon energy. To reduce CO_2 emissions, firms must thus enter the renewable energy market by purchasing clean energy produced by another company or engaging in M&A with an existing renewable energy company. This study showed that M&A with renewable energy firms significantly negatively influence firm value. The same result was found in the wind power analysis. Nevertheless, companies continue to undertake M&A with renewable energy firms because, among the various alternatives to reduce CO_2 emissions, the acquisition of a renewable energy firm is relatively cost-effective.

The result of this study is similar to those presented by previous analyses. For example, Leggio and Lien [27] analyzed mergers in the electric utility industry in terms of regulation. According to the authors, in a regulatory environment, firm M&A have a negative effect because they must be confirmed both by the regulator and by shareholders, leading to the firm incurring considerable costs and thereby reducing enterprise value.

Although this study contributed by applying the event study methodology, which has been widely used to analyze the effects of M&A, to the renewable energy field, its limitation was in the collection of data because of the lack of a clear definition and absence of a statistical system in the studied industry. Future research should aim to investigate mergers between large and small companies by reflecting on the industry characteristics of small firms.

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